Final Report for

Small-Scale Tropopause Dynamics and TOMS Total Ozone

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PROJECT OVERVIEW

This project used Earth Probe Total Ozone Mapping Spectrometer (EP TOMS) along-track ozone retrievals, in conjunction with ancillary meteorological fields and modeling studies, for high resolution investigations of upper troposphere and lower stratosphere dynamics. Specifically, high-resolution along-track (Level 2) EP TOMS data were used to investigate the beautiful fine-scale structure in constituent and meteorological fields prominent in the evolution of highly non-linear baroclinic storm systems. Comparison was made with high resolution meteorological models. The analyses provide internal consistency checks and validation of the EP TOMS data which are vital for monitoring ozone depletion in both polar and midlatitude regions.

Papers sponsored by the grant which were published in refereed journals:

1. "Fine-scale comparison of TOMS total ozone data and model analysis of an intense Midwestern cyclone"

J. Geophys. Rev., 105, 20,487-20,495 (2000)

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Abstract

High-resolution (about 40 km) along-track total column ozone data from the Total Ozone Mapping Spectrometer (TOMS) instrument are compared with high-resolution mesoscale numerical model analysis of an intense cyclone in the Midwestern United States. Total ozone increased by about 100 DU (nearly 38%) as the TOMS instrument passed over the associated tropopause fold region. Surprisingly complex organization is seen in the meteorological fields and compares well with the total ozone observations. Ozone data support meteorological analysis showing that stratospheric descent was confined to levels above about 600 hPa; significant positive potential vorticity at lower levels is attributable to diabatic processes. Likewise, meteorological fields show that two pronounced ozone streamers extending north and northeastward into Canada at high levels are not bands of stratospheric air feeding into the cyclone; one is a channel of exhaust downstream from the system, the other apparently previously connected the main cyclonic circulation to a southward intrusion of polar stratospheric air and advected eastward as the cut-off cyclone evolved. Good agreement between small-scale features in the model output and total ozone data underscores the latter's potential usefulness in diagnosing upper-tropospheric/lower-stratospheric dynamics and kinematics.

2. "The Role of Stratospheric Air in a Severe Weather Event: Analysis of PV and Total Ozone"

J. Geophys. Rev., 106, 11,813-11,823 (2001)

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Abstract

The role of dry stratospheric air descending to low and middle tropospheric levels in a severe weather outbreak in the Midwestern United States is examined using NCEP Eta model output, Rapid Update Cycle (RUC) analyses, and Earth Probe Total Ozone Mapping Spectrometer (EP/TOMS) total ozone data. Backward trajectories show stratospheric air descended to 800 hPa just west of the severe convection in the region. Damaging surface winds not associated with thunderstorms also occurred in the region of greatest stratospheric descent. Small-scale features in the high-resolution total ozone data compare favorably with geopotential heights and potential vorticity fields, supporting the notion that stratospheric air descended to near the surface. Detailed vertical structure in the potential vorticity appears to be captured by the small-scale total ozone variations. The capability of the total ozone to identify mesoscale features assists model verification. The total ozone data suggest biases in the RUC analysis and Eta forecast of this event. The total ozone is also useful in determining whether potential vorticity is of stratospheric origin or is diabatically generated in the troposphere.

3. "Evidence of stratosphere-to-troposphere transport within a mesoscale model and Total Ozone Mapping Spectrometer total ozone"

J. Geophys. Rev., 106, 27,323-27,334 (2001)

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Abstract

We present evidence for stratospheric mass transport into, and remaining in, the troposphere in an intense midlatitude cyclone. Mesoscale forecast model analysis fields from the Mesoscale Analysis and Prediction System (MAPS) were compared with total ozone observations from the Total Ozone Measurement Spectrometer (TOMS). Coupled with parcel back-trajectory calculations, the analyses suggest two mechanisms contributed to the mass exchange: (1) A region of dynamically-induced exchange occurred on the cyclone's southern edge. Parcels originally in the stratosphere crossed the jet core and experienced dilution by turbulent mixing with tropospheric air. (2) Diabatic effects reduced parcel potential vorticity (PV) for trajectories traversing precipitation regions, resulting in a ``PV-hole" signature in the cyclone center. Air with lower-stratospheric values of ozone and water vapor was left in the troposphere. The strength of the latter process may be atypical. These results, combined with other research, suggest that precipitation-induced diabatic effects can significantly modify (either decreasing or increasing) parcel potential vorticity, depending on parcel trajectory configuration with respect to jet core and maximum heating regions. In addition, these results underscore the importance of using not only PV but also chemical constituents for diagnoses of stratosphere-troposphere exchange (STE).

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